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PREPRINT

AIRFIELD REPAIRS IN AUSTERE LOCATIONS USING PELLETIZED ASPHALT TECHNOLOGY

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ABSTRACT

The use of pelletized asphalt technology to produce airfield-quality hot-mix asphalt (HMA) is evaluated in this study. The pelletization process produces HMA mix components (asphalt cement, fine aggregate, fiber, and polymer) as a pre-manufactured product that can be shipped at ambient temperature to austere locations. There, it can be introduced to locally-produced, heated coarse aggregate in a continuous or batch plant. Two HMA mix types known to provide high shear and rutting resistance were designed and subjected to laboratory tests; one was the stone mastic asphalt (SMA) mix and the other was a dense-graded airfield (DGA) HMA mix. Laboratory tests using the asphalt pavement analyzer indicated that DGA mixes had better rutting resistance compared to the SMA mixes. Thus, the test sections (one pelletized mix and one conventional HMA mix) at Silver Flag Test Area were built using the DGA mix gradation. The conventional HMA mix served as the experimental control. The test sections were trafficked with 1,500 passes of the F-15E load cart to evaluate the rutting performance of the pelletized asphalt HMA. The pelletized asphalt HMA section showed no rutting. The conventional asphalt test section, on the other hand, exhibited as much as 22 mm of rutting. The study concluded that it is feasible to produce airfield-quality HMA with pelletized asphalt using conventional HMA plants. Conventional construction equipment was adequate for placing a durable and rut-resistant pelletized HMA pavement. This paper presents results of laboratory and field tests and provides status of field implementation of the technology.

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BACKGROUND

Producing airfield quality Hot Mix Asphalt (HMA) is complicated requiring precise control of HMA components (binder, coarse and fine aggregate, and admixtures) and HMA mix plant. Most HMA problems can be traced to improper HMA production at the plant once the HMA job mix formula (JMF) has been perfected using laboratory tests. The pelletized asphalt technology provides precise controlled premixed HMA components and produces HMA mix components (asphalt cement, fine aggregate, fiber, and polymer) as a pre-manufactured product that can be shipped at ambient temperature to a remote location. Several major construction factors directly impact the ultimate performance of the airfield repair using HMA. These include: 1) asphalt-aggregate mix design, 2) construction procedure used to produce, place and compact the mix, and 3) quality of construction (workmanship).

The current method to perform airfield repairs using HMA is both time consuming and labor intensive. This requires specifying and ordering HMA from a local producer and using contract or in-house troop labor to repair the airfield. This may not be a viable plan for airfields located in austere locations where local HMA producers might not be present or may lack the capability to produce airfield quality HMA.

Convenient transport of asphalt binder is essential due to its visco-elastic nature requiring special handling and storage using specialized equipment and facilities. Pelletization technology is a promising alternative that allows for storage and transportation of asphalt mix components without the addition of any modifiers. The pelletized asphalt has a long shelf-life and can be stored at ambient temperatures. When needed, pelletized asphalt is introduced to locally-produced, coarse aggregate in a batch or continuous HMA plant to get a desirable HMA mix.

OBJECTIVE

Air Force Civil Engineering Support Agency (AFCEA) funded the Air Force Research Laboratory (AFRL) to evaluate the use of pelletized HMA for airfield damage repairs (ADR). The asphalt pellets and the related production technology developed and patented by NiTech Corporation represent one of the main features aimed at developing new procedures for repairing damaged airfields. Therefore, the research objective of this study was to develop and implement a mix design for pelletized asphalt that will be both workable during construction and that will perform satisfactorily when subjected to aircraft traffic. The study evaluated two mix types that are known to provide high shear and rutting resistance. First, the study evaluated a stone mastic asphalt (SMA) mix, and then a dense-graded asphalt (DGA) HMA mix. The research included development and field evaluation of the ability of these mix types to produce the most effective airfield pavement mixture, particularly when performing as an airfield damage repair material.

SCOPE

AFRL designed two pelletized asphalt candidate mixes (one SMA and one DGA) for optimal asphalt and air voids content and evaluated the mixes using both laboratory, as well as field tests. Laboratory and field tests were conducted on HMA mixes using both pelletized asphalt technology and mixes using a conventional asphalt binder, which served as the control mix. Laboratory tests for workability and rutting potential were conducted to assist in the selection of one of the HMA mixes for full-scale accelerated field trials to evaluate field performance of the selected mix type under simulated aircraft traffic. Evaluation of pelletized asphalt technology both in the laboratory and in the field, as an alternative airfield pavement repair process, is discussed in this paper.

PELLETIZED ASPHALT TECHNOLOGY

The pelletized asphalt technology of Nitech Corporation allows free flowing asphalt to be concentrated into a dry mix and stored in the form of small, 'pea' shaped pellets at ambient temperature (Figure 1). The asphalt pellets are coated with a patented two-step process utilizing a polymer emulsion followed by a fine powder, usually clay. This prevents the asphalt from sticking together. These pellets can then be mixed with stone aggregate heated both on site and on demand to create DGA or SMA paving HMA.

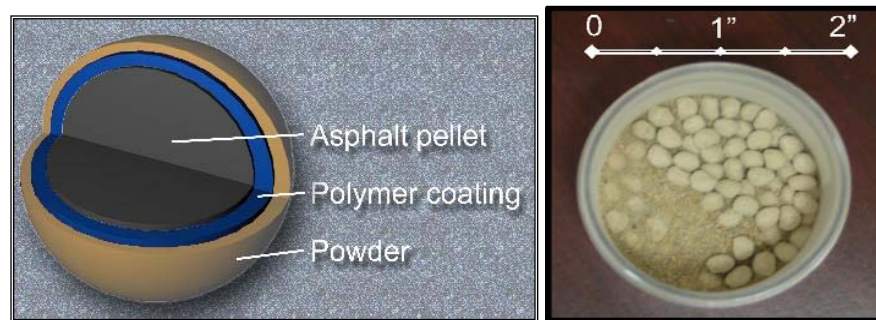


FIGURE 1 Pelletized asphalt consists of asphalt binder, fine aggregate and filler materials.

The polymer forms a continuous non-tacky coating because both the polymer and powder are fully compatible with the base material. Coating is precisely controlled and the typical thickness ranges from 0.002-0.010 inches. Asphalt pellets initially developed had a tendency to interlock due to deformation under pressure owing to their soft nature. To resolve this issue Nitech Corporation developed the NiPak technology (patent still pending). In the NiPak process a portion of the fines (minus #30 fines) is added to the pellets during the manufacturing process. These fines fill the crevices between the pellets and eliminate the point contact thus creating a uniform hydrostatic pressure around the pellets which minimizes deformation and interlocking of the distorted asphaltic solids (Figure 2).

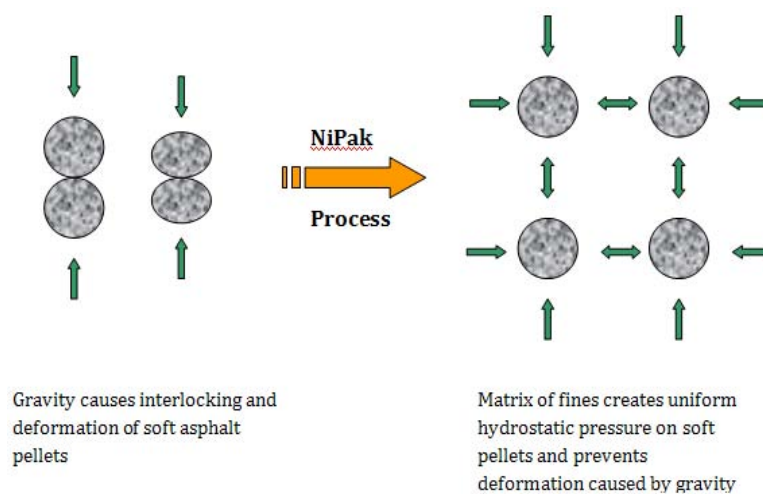


FIGURE 2 NiPak technology packages asphalt pellets with a portion of JMF fines.

The addition of these fines creates a shippable, storable asphalt pellet product which has a stable shelf-life of approximately 10 years at ambient temperatures of up to 130 °F and which can be poured as a free flowing material from shipping containers into a continuous or batch mixing plant to produce HMA on demand.

Fines are selected as per the mix design and packed with pellets, along with other additives such as fiber, lime, etc. To produce the HMA or SMA mix, coarse aggregate is heated on site with a portable heater/mixer unit or in a conventional HMA plant until it reaches the desired temperature. The pre-packaged asphalt pellet mix is then stored at ambient temperature prior to being introduced to the hot/dried aggregate. The advantages of pelletized HMA include:

- Allows for rapid onsite production to facilitate expedient pavement repair
- PG grades such as 76-22 can be stored and transported at ambient temperature
- Can be mixed with locally produced aggregates in a deployable mix plant
- Testing indicates hot mix from pellets provides equivalent quality of conventional hot mix procured from batch or drum plants
- Saves energy costs associated with storing asphalt binder in special storage facilities

LABORATORY EVALUATION OF PELLETIZED HMA MIXTURE

The National Center for Asphalt Technology (NCAT) helped develop the HMA mix design for this study. The mix design requirements included sufficient mix effectiveness during construction and satisfactory performance when subjected to aircraft traffic. The design of the asphalt mixture was performed in compliance with United Facilities Guide Specifications (UFGS) currently adopted by the United States Air Force. In particular, HMA designs were based on the UFGS 32 13 15 (1) and UFGS 32 13 17 (2), which provide the guidelines for DGA and SMA mixtures, respectively. Four different HMA mixtures were designed applying the 75 blow Marshall Design method outlined in ASTM D 6926 – 04 (3). These mixtures were subsequently analyzed in terms of volumetric properties and performance. Two mixtures were DGA types and the other two were SMA. In particular, one of the DGA mixtures was characterized by a performance grade (PG) 76-22 polymer modified asphalt binder, whereas the other by a PG 76-22 pelletized asphalt binder. The same characterization was adopted for the SMA mixtures. The selected aggregate was limestone due to its availability for the Tyndall AFB field testing. Table 1 includes the aggregate gradation employed for the mixtures. Specimens of the DGA and SMA mixtures with asphalt pellets and standard binder were fabricated and checked for volumetric properties. Tables 1 and 2 show the characteristics of the mixtures; their volumetric parameters were within the UFGS tolerance limits (1 & 2). The target design air voids were 4% and 3.5% for the DGA and SMA mixtures, respectively. Stability and Flow measurements were not performed because they are not required by the UFGS for SMA mixtures.

TABLE 1 Mixture Gradations and Specification Limits for DGA and SMA mixes

| Sieve size | DGA mixture | USGS 32 12 15 range | SMA mixture | USGS 32 13 17 range |
|------------|-------------|---------------------|-------------|---------------------|
| 3/4" | 100 | 100 | 100 | 100 |
| 1/2" | 94 | 76-96 | 90 | 90-100 |
| 3/8" | 87 | 69-89 | 78 | 50-85 |
| #4 | 65 | 53-73 | 36 | 20-40 |
| #8 | 50 | 38-60 | 22 | 16-28 |
| #16 | 32 | 26-48 | 16 | - |
| #30 | 22 | 18-38 | 14 | - |
| #50 | 13 | 11-2.7 | 12 | - |
| #100 | 7 | 6-18 | 10 | - |
| #200 | 4.7 | 3-6 | 9.1 | 8-11 |

TABLE 2 Mixture Characteristics and Specification Limits

| Parameters | Ergon PG 76-22 | Pellets PG 76-22 | USFGS 32 12 15 range |
|--------------------|----------------|------------------|----------------------|
| DGA Mixture | | | |
| Optimum Pb (%) | 5.0 | 5.6 | - |
| Va | 4.0 | 4.0 | 3-5 |
| VMA | 14.9 | 15.9 | >14 |
| VFA | 81.6 | 73.5 | - |
| Stability (lb) | * | 4450 | >1350 |
| SMA Mixture | | | |
| Optimum Pb (%) | 5.8 | 6.3 | - |
| Va | 3.5 | 3.5 | 3-4 |
| VMA | 17.2 | 17.8 | >17 |
| VFA | 86.8 | 75.8 | - |

* Samples discarded before testing

Workability Testing

Testing was performed to evaluate the workability of these mixtures in order to estimate their compactibility in the field. HMA workability is related to the mixture gradation, binder type and content, additives, and temperature. In 2003, NCAT developed the equipment to measure workability (4). It consists of a paddle system pushed by a rotor fitted with a torque transducer. The torque required to maintain a given rate of revolution is recorded with a simple data acquisition system; torque at 120°C is assumed as reference value. The mixtures subjected to the workability tests were from standard asphalt binders, not from asphalt pellets. As shown in Figure 3, the DGA mixtures were characterized by lower values of torque than those required by the SMA mixtures. The measured torque at 120 °C was in the average of 44 Nm for the DGA mixtures, whereas for the SMA, the torque was in the average of 54 Nm. Torque was also evaluated at 140 °C and was in the average of 31 Nm for the DGA and 34 Nm for the SMA mixtures, respectively. In conclusion, the DGA mixture required less energy to work at both temperatures than the SMA mixture and therefore would allow better compactibility of the material when placed in the field.

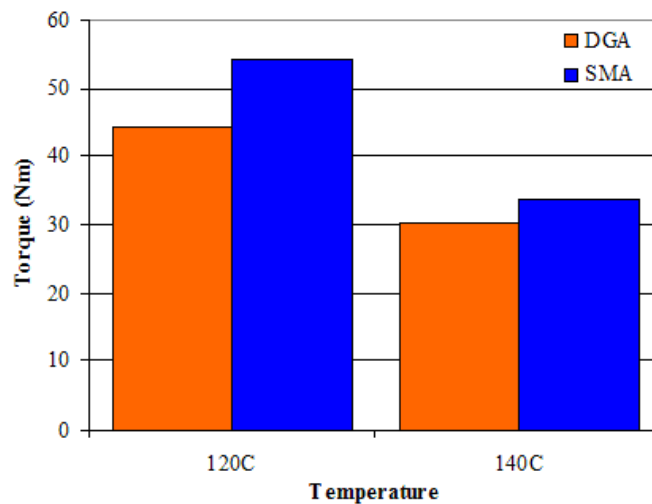


FIGURE 3 Workability measurements indicated DGA mixes to be slightly more workable.

Permanent Deformation Testing

To evaluate rutting (permanent deformation) susceptibility, based on AASHTO T 63 (5), samples were tested with the Asphalt Pavement Analyzer (APA). Both asphalt mixtures were subjected to load levels of 100 and 240 lbs; the latter is approximately the highest load the highway version of the APA can accommodate. An airfield version of the APA is currently under development. Under the 100-lbs wheel load, the DGA specimens showed good rutting performance (more resistance to permanent deformation) with an average rut depth of 2.8 mm. In particular, the DGA mixture, using pelletized asphalt, had a rut depth of 2.6 mm compared to 3.0 mm for the regular PG 76-22. The APA results for the SMA mixtures were higher with an average rut depth of 4.0 mm. When the mixture with asphalt pellets was tested under the 240 lbs wheel load, the DGA again performed better than the SMA. The rutting measure for the DGA mixture with pelletized asphalt was 4.3 mm, whereas the SMA had an average rut depth of 5.8 mm. Table 3 summarizes the results of the APA rutting tests.

TABLE 3 Rutting Measurements from the APA Tests

| Test parameters | 100-lb wheel load; 100-psi hose pressure | | 240-lb wheel load; 120-psi hose pressure | |
|-----------------|---|------------------------|---|------------------------|
| | Ergon PG 76-22 | Pelletized PG 76-22 | Ergon PG 76-22 | Pelletized PG 76-22 |
| DGA mixture | 3.0 mm | 2.6 mm | N/A | 4.3 mm |
| SMA mixture | 4.3 mm | 3.7 mm | N/A | 5.8 mm |

The laboratory results from the workability and rutting tests resulted in the selection of the DGA mixture. The DGA mixture was also selected due to its cost-effective design, lower binder content, less restrictive aggregate requirements, and the absence of stabilizing fibers as required in SMA. Thus, the DGA mixture was selected for the field testing at Tyndall AFB, FL.

FIELD EVALUATION OF PELLETIZED HMA MIXTURE

The field evaluation was conducted to determine the feasibility of producing pelletized HMA using a standard asphalt plant, ease of placement, and its performance under the simulated aircraft load using the F-15 load cart. Two test sections (30 ft by 50 ft) were built on the existing concrete runway at the Silver Flag training field at Tyndall AFB, FL. One section was built with the DGA mixture with conventional binder; the other was built using the pelletized asphalt mixture. The HMA mix was manufactured at a nearby batch plant and transported using standard end dump trucks. HMA was placed using an automated paver in two lifts each measuring 2-inches thick. After placing the first lift, HMA was compacted using a steel wheel roller. After adequate compaction, the second lift was placed and compacted with a steel wheel roller (vibratory mode on) followed by a pneumatic tire roller. The finish rolling was done with the steel wheel roller with the vibratory mode turned off.

Laboratory Testing During Construction

During construction, NCAT/AFRL personnel exclusively sampled and tested the asphalt mixture produced with asphalt pellets for quality control (QC) purposes. Additional material was retrieved from the plant for binder testing at the NCAT laboratory. On site, the sampled mixture was tested for gradation and asphalt content. Table 4 includes the gradation and the acceptance limit included in the UFGS 32 12 15 results. The percentage passing the No. 200 sieve was outside the acceptance range imposed by the specifications; primarily due to the difficulty the contractor had when handling the asphalt pellets prior to production. As previously described, the asphalt pellets are packed within a matrix of fine aggregates that prevents conglomeration of the pellets during shipment and storage. However, the fines matrix used for shipment of the pellets for this demonstration project were not the same ones used in the mix design; therefore, the fines matrix in the pellet containers had to be removed prior to adding the pellets at the plant. Some of those fines from the shipment of pellets were not completely removed and, as a result, the gradation of the produced mixture was adversely affected. The percent passing the No. 200 sieve was higher than permitted by the UFGS specification. The bulk and maximum theoretical specific gravity (Gmb and Gmm) were also measured and equal to 2.401 and 2.590, respectively. The percentage of air voids (Va) was 7.3, and the asphalt content extracted through the ignition oven procedure in accordance with AASHTO T 308 (6) was equal to 5.48 %.

TABLE 4 Pelletized HMA QC Testing Indicated Excess Minus #200 Material

| Sieve size | Percent Passing | UFGS 32 12 15 limits |
|------------|-----------------|----------------------|
| 3/4" | 100.0 | 92-100 |
| 1/2" | 97 | 68-100 |
| 3/8" | 92 | 61-97 |
| #4 | 68 | 45-81 |
| #8 | 516 | 32-66 |
| #16 | 35 | 20-54 |
| #30 | 26 | 12-44 |
| #50 | 20 | 5-33 |
| #100 | 16 | 4-20 |
| #200 | 12.8 | 1-8 |

The construction of each section required two truck loads of HMA. Temperatures of both standard and pelletized asphalt mixtures were taken at the plant before delivery and placement of the material. On the first truck, containing the pelletized asphalt HMA, the temperatures were between 188 °F on the top, and 300 °F in the mass center. These values were higher than the temperatures of the conventional asphalt HMA before delivery, which were between 195 °F on the top, and 260 °F in the mass center. The temperature of the pelletized asphalt HMA in the second truck load was even higher – between 226 °F and 397°F resulting in the mixture being overheated. The high temperatures were caused by an increase in the aggregate heating temperature before mixing with the asphalt pellets. The temperature was set to 350 °F and then increased to 400-410 °F. For the conventional asphalt mixture, the aggregate heating temperature was about 300-310 °F. The temperature adjustment was independently adopted by HMA producer to assure complete melting and mixing of the asphalt pellets with the aggregate material. This correction produced an overheated material, possibly damaging the asphalt binder.

The NCAT laboratory performed a series of testing on the binder extracted from mixture samples through the Rotovap process following ASTM D 5404 (7) protocols to evaluate if changes in asphalt binder characteristics occurred during production. The binder tests included the Pressure Aging Vessel (PAV), the Dynamic Shear Rheometer (DSR), and the Bending Beam Rheometer (BBR). The tested binder was extracted from the pelletized asphalt HMA samples from the first and second truck load and from the mixture produced through a mobile HMA plant. The latter mixture was delivered directly to the NCAT laboratory facility from the mobile mixer testing site. The original and recovered binders were graded according to the guidelines contained in the ASTM D 6373-07E1 (8). The asphalt binder from the pelletized asphalt was tested before and after the aging process through the rolling thin film oven (RTFO) following ASTM D 2872-04 (9). Table 5 reiterates the critical temperature values inferred from the analysis of the test results.

TABLE 5 Extracted Binder Critical Temperatures Analysis Indicated Binder Aging

| Criteria | Pelletized Asphalt | | Field Trials | | |
|--|--------------------|-----------|--------------|----------|----------|
| | Not aged | RTFO aged | Field mixer | Truck #1 | Truck #2 |
| 1. DSR RTFO | | | | | |
| T_{\max} for $G^*/\sin\delta = 2.20$ kPa | 76.9 | 85.4 | 96.0 | 88.8 | 101.8 |
| 2. DSR PAV | | | | | |
| T_{int} for $G^*\sin\delta = 5,000$ kPa | 23.0 | 24.7 | 27.6 | 25.4 | 29.0 |
| 3. BBR PAV | | | | | |
| T_{\min} for $S(t) = 300$ MPa | -29.2 | -24.8 | -23.2 | -24.6 | -38.2 |
| T_{\min} for $m = 0.300$ | -28.9 | -24.1 | -22.7 | -23.9 | -19.2 |

The analysis indicates changes in the binder PG during HMA production. There is a variation in performance grade when the binder is worked in the asphalt plant as illustrated by the simulated aging through the RTFO process. The outcomes are also confirmed by the tests on the mixture sampled from the first truck load (Truck #1), as shown in Table 5. The test results on the material from the second truck load (Truck #2) confirmed the effect of overheating on binder performance grade. Overheating changed the performance grade of the binder that was originally PG 76-22. Data for the field mixer also indicates changes in performance grade from

the theoretical PG 76-22 to a stiffer PG 94-22. The higher values of the intermediate temperatures suggested that the binder from the second truck load and the mobile mixer were stiffer and may therefore, be more susceptible to fatigue cracking. In contrast, the intermediate temperatures evaluated for the extracted binder from pellets (before and after aging) in truck load #1 were within acceptable range, therefore no change of binder performance is anticipated. Similarly, the lower temperatures were affected by the production process. The binders from the first truck load and the pellets were within acceptable values, whereas the binders from the second truck load and the mobile device were clearly affected by the production process, thus limiting performance at lower temperatures.

Field Testing for Permanent Deformation

Accelerated load testing with the F-15 load cart helped determine the rutting susceptibility of the test sections. Both the conventional and pelletized asphalt HMA sections were trafficked with 1500 passes of AFRL's F-15E load cart (Figure 4), using a channelized trafficking pattern. The test wheel representing the main gear of the F-15 was inflated to 315 psi and carried a load of 35,200 lbs. Five lanes spaced 12-inches apart were marked and trafficked using the F-15 load cart. Traffic was simulated by driving the load cart forward and backward over the length of the test section and then shifting the path of the load cart laterally to move on to the next marked lane. Loading was normally distributed across a 48-inch "wander" width in the 5 lanes which were spaced at 12-inches center to center. Load application was continued until reaching 1500 passes or failures, whichever occurred first. Failure was defined as permanent deformation of 1-inch (25 mm) or greater.



FIGURE 4 F-15E load cart testing helped evaluate rutting resistance of test sections.

Elevation surveys using a rod and level determined the transverse profile (rutting) of the test section pavement. Measurements were taken at 3-inch intervals for a distance of 30-inches on either side of the centerline of the wheelpath, at five transverse intervals (5, 10, 15, 20, and 25 ft) along the length of the test section. Also, a straightedge was used to measure maximum rut depth at the same transverse intervals. Measurements were made after completing 10, 16, 32, 48, 80, 112, 160, 256, 512, 752, 1008, 1248, and 1504 passes with the load cart. Figure 5 shows the permanent deformation measurements after 0, 512, 752, 1008, 1248, and 1504 passes of the F-15 load cart. No permanent deformation was observed in the pelletized asphalt, whereas the

conventional asphalt showed considerable deformation. The maximum deformation observed in the conventional asphalt after 1504 passes was 22.5 mm; 2.5 mm short of the defined failure criteria.

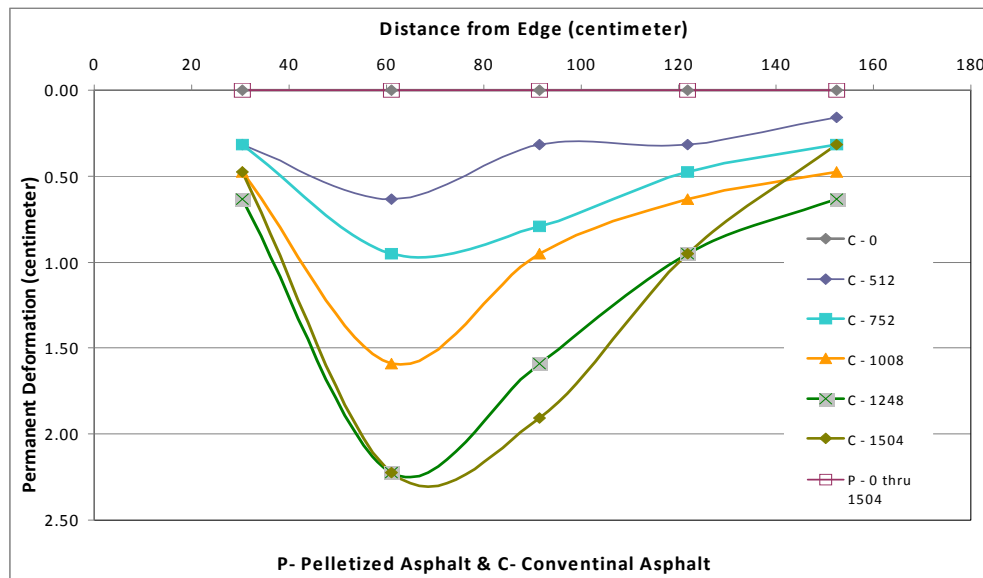


FIGURE 5 Permanent deformation versus load cycles results for field experiments.

CONCLUSIONS

Following are the general conclusions with regard to the pelletized and conventional asphalt HMA evaluated and compared during this research effort:

1. Pelletized asphalt can be used in conjunction with locally available aggregates to produce an equivalent or higher performance mix than those produced using conventional asphalt binders.
2. Between the two mixtures tested in the laboratory, workability tests indicated that the DGA mixture required less energy than the SMA mixture and therefore allows for better compaction of the material when placed in the field.
3. APA tests with load levels of 100 and 240 lbs indicated that the DGA performed better than the SMA mixture, with the DGA showing lower average rut depth.
4. The DGA mixture was also found to be more cost-effective than the SMA mixture due to its lower binder content, less restrictive aggregate requirements, and the absence of stabilizing fibers as required in SMA.
5. During construction of the test sections, samples of the asphalt mixture produced with asphalt pellets had percentages passing the No. 200 sieve outside the acceptance range of the specifications. This result was due to the difficulty the contractor had when handling the asphalt pellets prior to production and when separating the fines matrix from the shipping containers.
6. Temperature analysis data for both standard and pelletized asphalt mixtures indicated that the asphalt pellets mixture overheated during production.
7. Construction of test sections helped verify that it is feasible to manufacture, transport, and place pelletized asphalt HMA using conventional HMA plant standard dump trucks, and paving equipment.

8. Load cart testing on the test sections indicated that the pelletized asphalt section had improved resistance to permanent deformation as compared to the test section constructed with conventional asphalt binder.

RECOMMENDATIONS

General recommendations from field observations include the following:

1. The temperature during production should be closely monitored to avoid overheating which can negatively influence binder performance.
2. Future tests on the HMA produced by the mobile device are warranted to determine if the device inherently ages the binder.
3. Density and volumetric analysis of field cores is also recommended to assess the compactability of the mixture during field implementation.

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